Adv. Sci. Res., 11, 7–10, 2014
www.adv-sci-res.net/11/7/2014/
doi:10.5194/asr-11-7-2014

Advances in Science & Research
Open Access Proceedings

13th EMS Annual Meeting & 11th European Conference on Applications of Meteorology (ECAM)

Prototype of a drought monitoring and forecasting system for the Tuscany region

R. Magno[1,2], L. Angeli[1], M. Chiesi[2], and M. Pasqui[2]

[1]LaMMA Consortium, Sesto Fiorentino, Florence, Italy
[2]Institute of Biometeorology, National Research Council, Florence, Italy

Correspondence to: R. Magno (magno@lamma.rete.toscana.it)

Received: 15 January 2014 – Revised: 1 April 2014 – Accepted: 3 April 2014 – Published: 12 May 2014

Abstract. A system for drought monitoring and medium–long time forecasting in the Tuscany region (central Italy) is briefly introduced, which is based on ground and satellite data (1 km spatial resolution and 16-day temporal resolution). It is also shown how information about current conditions and future evolution of a drought event is periodically delivered on the LaMMA Consortium website, in collaboration with the Institute of Biometeorology (IBIMET-CNR).

1 Introduction

With respect to other extreme climatic events, drought is a creeping and complex phenomenon (Gillette, 1950; Tannehill, 1947), characterized by a slow and often long-lasting evolution: its onset and withdrawal are generally difficult to define (Iglesias et al., 2009); its intensity and extension are spatially and temporally extremely variable; and the impacts produced on the environment can arise later and persist even after its end (Vicente-Serrano et al., 2012). As demonstrated by other authors (e.g., Jayaraman et al., 1997; Brown et al., 2008; Jain et al., 2010), a comprehensive framework including a climate-based, satellite-derived monitoring and a seasonal weather forecast is the most reliable way to identify drought occurrence and trends and to deliver timely information for impact reduction. In this study a proactive, integrated drought monitoring and seasonal forecasting tool is briefly illustrated; it was implemented for the Tuscany region (Italy/central Mediterranean) by the LaMMA Consortium and the Institute of Biometeorology (IBIMET-CNR), and aims at filling the temporal gap between the development of a dry period and the response of final users in managing drought-related emergencies, by delivering maps and information in quasi-real-time.

2 The operational chain

The operational chain implemented to calculate drought indices and deliver final products for drought monitoring and forecasting in Tuscany is based on semi-automatic procedures (see Fig. 1).

2.1 The monitoring component

The monitoring component is developed by integrating the state-of-the-art science and technologies and by selecting a set of coupled rainfall-based and satellite-derived indices that follow several criteria: (1) types of drought, (2) availability and consistency of data, (3) geographical characteristics, (4) time and spatial variability, (5) main final users. For our operational framework two rainfall-based indices were identified, being considered more representative than others (Morid et al., 2006): the Standardized Precipitation Index (SPI) (McKee et al., 1993) and the Effective Drought Index (EDI) (Byun et al., 1999). The SPI, a robust and reliable index (Heim, 2002; Keyantash and Dracup, 2002), provides multiple timescale drought occurrence and detects its variation and duration; the EDI, which is calculated on a daily basis, is thus more sensitive to each single rainfall event and tracks the influence of precipitation on the recovery from an accumulated deficit. Additionally EDI is effective to spatially recognize the onset of a drought episode (Morid et al., 2006). The satellite-derived indices are focused on the vegetation

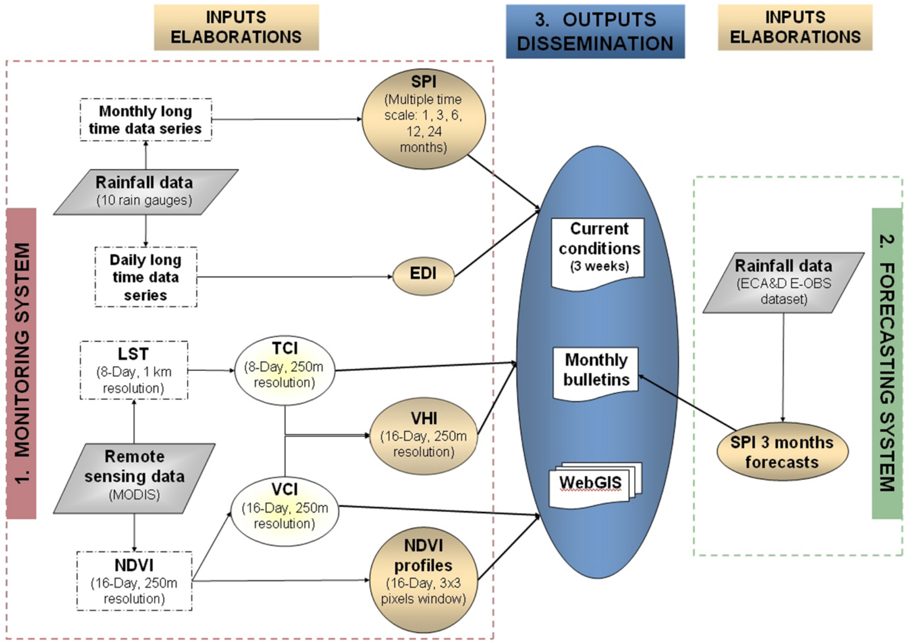

Figure 1. Schematic representation of the drought monitoring and forecasting system components.

performances related to temperature and moisture stress and are based both on the Normalized Difference Vegetation Index (NDVI) and the Land Surface Temperature (LST), elaborated from Terra MODIS (Moderate Resolution Imaging Spectroradiometer) images to obtain the comprehensive Vegetation Health Index (VHI) (1 km spatial resolution) (Kogan, 1995) (see Fig. 2). These indices represent an indirect drought responsive way to analyze the phenomenon and are widely applied due to their capability to describe in more detail the spatial characteristics of temporal drought dynamics (Wan et al., 2004). They constitute the core of our monitoring system during the growing season (spring and summer), when problems related to the cloud cover, typical of the northern part of the Mediterranean region, are generally reduced with respect other periods.

2.2 The seasonal forecast component

An empirical multi-regressive approach, based on observed climate indices, is adopted to produce seasonal forecasts for the 3-month SPI. This component provides an estimate of the spatial and temporal distribution of climate anomalies up to 3 months into the future. These seasonal forecasts follow a physically based empirical approach based on a multi-regressive method (Pasqui et al., 2009): it estimates the multi-linear relations of a data set of observed oceanic and atmospheric predictors, on a monthly and 3-monthly basis, with SPI values with respect to the 1981–2010 training period. Oceanic and atmospheric predictors, along with their relative leading time are selected according to the best correlation with the target SPI values over the target area (see Pasqui et al. (2009) for the complete list of predictors). The multi-regressive coefficients, computed over the training period, are then used to forecast the expected SPI values according to the last observed values of selected predictors. The 3-month SPI dates are computed from the daily E-OBS gridded precipitation data set (period from 1950 to 2013) from the ECA&D (European Climate Assessment & Dataset) project, providing the reference framework for seasonal drought evolution outlooks.

3 Product dissemination

Index analysis and final products must be easily delivered to ensure the end users useful, effective and timely information for their final needs: the internet is the best way to disseminate drought monitoring and forecasting alerts. To this aim, information is delivered at different time steps:

- During the growing season, vegetation conditions of the previous 16 days are updated on a specific page of the Consortium website, with a lag of about 1 week. This is done analyzing the NDVI profiles and the VHI index (http://www.lamma.rete.toscana.it/siccita-situazione-corrente).
- Online monthly bulletins (http://issuu.com/consorziolamma), on the other hand, provide a more detailed description of drought evolution throughout a joint analysis of satellite- and climate-based drought indices during the previous 30 days, with focus on forest types and main tree crops. A forecast of the SPI index for the next months is also provided.

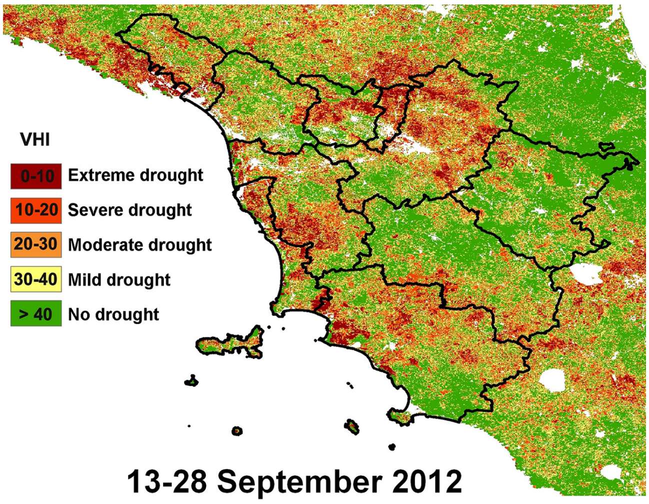

Figure 2. Vegetation Health Index (VHI) referred to the bi-weekly period 13–28 September 2012.

– A WebGIS application (http://www.lamma.rete.toscana.it/webgis-siccita) based on open source solutions has been customized in order to integrate different data sets and share maps of drought indices with decision-makers and other stakeholders (Rocchi et al., 2010).

Statistics of the online monthly bulletin web accesses after 18 months of operational drought monitoring and forecast indicate that, on average, there are about 1200 specific contacts, with peaks during the end of spring and summer. Even in cold seasons when drought events occur (like in 2012), a large number of contacts were registered (see Fig. 2).

4 Conclusions and future perspectives

The described monitoring and forecasting systems are active all over the year, following and assessing the temporal and spatial evolution of possible drought events and integrating heterogeneous data: climate-based and vegetation indices. Bulletins emission follows a monthly to bi-weekly basis scheme providing information on the vegetation response to possible drought conditions. Due to the importance of the terrestrial water budget and in order to provide a better tool for natural and agricultural resources management, especially during drought events, a simplified "water balance model" has been also implemented and is under verification; it provides an estimate of actual evapotranspiration (ET_A) with a high spatiotemporal resolution, based on ground and remote sensing data (Chiesi et al., 2013). The model combines estimates of potential evapotranspiration (ET_0) and of fractional vegetation cover derived from NDVI, in order to simulate both transpiration and evaporation processes. Current results and further ongoing validations indicate a promising valuable operational use on Tuscany areas where vegetation cover is fragmented and agriculture is often represented by annual rotating crops.

Acknowledgements. The authors thank their colleagues Fabio Maselli and Luca Fibbi for assisting during the development of the simplified water balance model and Bernardo Gozzini for continuously supporting new ideas. This research was partly supported by the project "Llnking Long Term Observatories with Crop Systems Modeling For a better understanding of Climate Change Impact and Adaptation StRategies for Italian Cropping Systems" (IC-FAR; www.icfar.it), and it also contributes to the knowledge hub "Modelling European Agriculture with Climate Change for Food Security" (MACSUR; www.macsur.eu) within the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI; www.faccejpi.com).

Edited by: C. Buontempo
Reviewed by: two anonymous referees

References

Brown, J. F., Wardlow, B. D., Tadesse, T., Hayes, M. J., and Reed, B. C.: The Vegetation Drought Response Index (VegDRI): A New Integrated Approach for Monitoring Drought Stress in Vegetation, GIScience & Remote Sensing, 45, 16–46, 2008.

Byun, H. R. and Wilhite, D. A.: Objective Quantification of Drought Severity and Duration, J. Climate, 12, 2747–2756, 1999.

Chiesi, M., Rapi, B., Battista, P., Fibbi, L., Gozzini, B., Magno, R., Raschi, A., and Maselli, F.: Combination of ground and satellite data for the operational estimation of daily evapotranspiration, European J. Remote Sens., 46, 675–688, 2013.

Gillette, H. P.: A creeping drought under way, Water and Sewage Works, March, 104–105, 1950.

Heim Jr., R. R.: A review of twentieth-century drought indices used in the United States, B. Am. Meteorol. Soc., 83, 1149–1165, 2002.

Iglesias, A., Garrote, L., Cancelliere, A., Cubillo, F., and Wilhite, D. A.: Coping with drought risk in agriculture and water supply systems. Drought Management and Policy Development in the Mediterranean Series: Advances in Natural and Technological Hazards Research, 26, XVIII, 322 pp., 2009.

Jain, S. K., Keshri, R., Goswami, A., and Sarkar, A.: Application of meteorological and vegetation indices for evaluation of drought impact: a case study for Rajasthan, India. Natural Hazards, 54, 643–656, 2010.

Jayaraman, V., Chandrasekhar, M. G., and Rao, U. R.: Managing the natural disasters from space technology inputs, Acta Astronautica, 40, 291–325, 1997.

Keyantash, J. and Dracup, J. A.: The quantification of drought: an evaluation of drought indices, B. Am. Meteorol. Soc., 83, 1167–1180, 2002.

Kogan, F. N.: Application of vegetation index and brightness temperature for drought detection, Adv. Space Res., 15, 91–100, 1995.

McKee, T. B., Doesken, N. J., and Kliest, J.: The relationship of drought frequency and duration to time scales, Proceedings of the 8th Conference of Applied Climatology, Anaheim, CA, 179–184, 1993.

Morid, S., Smakhtin, V., and Moghaddasi, M.: Comparison of seven meteorological indices for drought monitoring in Iran, Int. J. Climatol., 26, 971–985, 2006.

Pasqui, M., Primicerio, J., Benedetti, R., Crisci, A., Genesio, L., and Maracchi, G.: Seasonal forecasting precipitation in the Mediterranean basin. Managing water in a changing world, International Conference hosted by the Commission for Water Sustainability International Geographical Union (IGU), Torino, Italy. 2009.

Rocchi, L., De Filippis, T., and Magno, R.: An open source general-purpose framework for implementing webGIS applications. FOSS4G International Conference for Open Source Geospatial Software. Barcelona (Spain), 2010.

Tannehill, I. R.: Drought: Its Causes and Effects, Princeton University Press, Princeton, New Jersey, 1947.

Vicente-Serrano, S. M., Beguería, S., Lorenzo-Lacruz, J., Camarero, J. J., López-Moreno, J. I., Azorin-Molina, C., Revuelto, J., Morán-Tejeda, E., and Sanchez-Lorenzo, A.: Performance of drought indices for ecological, agricultural and hydrological applications, Earth Interactions, 16, 1–27, 2012.

Wan, Z., Wang, P., and Li, X.: Using MODIS land surface temperature and normalized difference vegetation index for monitoring drought in the southern Great Plains, USA, Int. J. Remote Sens., 25, 61–72, 2004.